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Sport specific assessment of inter-limb
asymmetries: A way to reduce injuries

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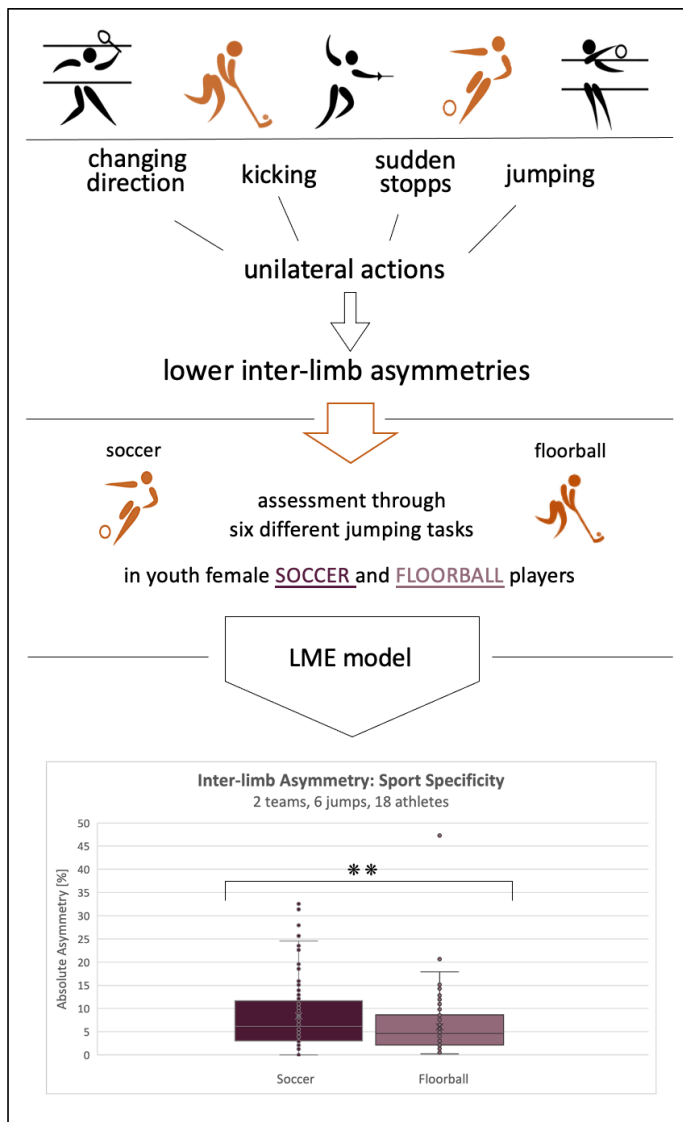
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Sport specific assessment of inter-limb asymmetries:

A way to reduce injuries



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In Brief:

Assessment of lower inter-limb asymmetries in youth female soccer and floorball players, aiming to detect sport specific differences by using a linear mixed effect (LME) model.

Highlights:

- In this study a significant difference of inter-limb asymmetries in soccer and floorball players was observed, indicating a higher asymmetry in soccer. This suggests that asymmetries may not only be task but also sport specific.
- Overall, leg dominance was not correlated with asymmetry.

Project of the National contest for Swiss Youth in Science

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Abstract

In recent years, lower inter-limb asymmetries have become a topic of increasing interest in sports research. Numerous studies have investigated the occurrence of between-limb differences in a variety of physical tests, ranging from strength, sprinting, and change of direction speed to jumping tasks. The main focus has been the association of asymmetries to either enhanced injury risk or reduced physical performance. Sport specific aspects and differences of lower limb asymmetries have not often been analysed. Additionally, most studies have been performed with male athletes. Women, however, present higher prevalence of lower limb asymmetries in strength, coordination, and postural control than men. These two aspects were therefore addressed in the present study.

Female youth soccer ($n=18$, age: 16.7 ± 0.8 years) and floorball ($n=18$, age: 17.6 ± 0.9 years) players completed a test battery consisting of six unilateral jumping tasks in horizontal and lateral direction to detect sport specificity in inter-limb asymmetries. The test comprised the following hops: (1) Single Leg Hop for Distance and (2) a newly created version of it, (3) Single Leg Triple Hop, (4) Single Leg Crossover Hop, (5) Side Hop and (6) Single Leg 6-meters Timed Hop. The scores of every jump were calculated into Limb Symmetry Indexes for each participant.

A linear mixed effect (LME) model (using function lmer in program R) was applied to evaluate the effects of sport and jump type on asymmetries. In terms of the whole test battery, there was a significantly higher magnitude of asymmetries in soccer compared to floorball ($p=0.0067$) with a mean difference of 1.9%. Three significant differences between the effects of different jump types were detected (5>2: $p=0.027$; 5>3: $p<0.001$; 5>6: $p=0.014$). Moreover, the results showed no significant effect on leg dominance.

According to the findings of this study, soccer appears to be more asymmetric than floorball, leading to the suggestion that inter-limb asymmetries may not only be task-specific, but also sport-specific. Since no significant correlations were detected, this study suggests that inter-limb asymmetries are independent of leg dominance.

Considering the possible reduction in athletic performance and increasing injury risk, strength and conditioning coaches are advised to assess athletes' inter-limb asymmetries using a broad, sport specific test battery and decrease them.

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1 Introduction

Injuries not only result in pain, decreased physical activity and lost work time but also in outstanding medical costs (Murphy, Connolly, & Beynnon, 2003; Sammelstelle für die Statistik der Unfallversicherung UVG, 2020). In Switzerland sports-related accident costs have risen distinctively during the last years with effective costs increasing about 40% from 2011 to 2019, reaching the mark of one billion Swiss Francs per year for the first time in 2014 (Sammelstelle für die Statistik der Unfallversicherung UVG, 2020). More than one quarter of these costs arise in ball sports, especially soccer (annual average from 2015 to 2019) (Sammelstelle für die Statistik der Unfallversicherung UVG, 2020). Prevention and intervention of possible risk factors have become pivotal topics for researchers and clinicians (Murphy, Connolly, & Beynnon, 2003).

Interlimb-asymmetries are one of these possible risk factors for sport injuries (Helme, Tee, Emmonds, & Low, 2021). They can be defined as the percentage difference between limbs when measuring unequal performance scores in a given task, for example in jumping tests (Keeley, Plummer, & Oliver, 2011; Bishop, Read, Lake, Chavda, & Turner, 2018a). Considering that from an anatomic and neurological perspective the human body is asymmetric itself, being asymmetric during movement is common to a certain extent (Afonso, et al., 2020). In recent years, inter-limb asymmetries in the context of sports have become a highly researched source of investigation (Bishop, Turner, & Read, 2018c; Madruga-Parera, et al., 2020; Bishop, et al., 2021b; Fort-Vanmeerhaeghe, Bishop, Buscà, Vicens-Bordas, & Arboix-Alió, 2021; Bishop, et al., 2021a). On the one hand, in injured athletes, inter-limb asymmetries are assessed through functional tests in the field of rehabilitation as return-to-sport criteria (Bishop, Turner, & Read, 2018b; Wilke, Grimm, Hoffmann, & Froböse, 2018).

On the other hand, a vast amount of studies focused on uninjured athletes, investigating the prevalence of between limb differences in a variety of physical tests, ranging from strength, sprinting and change of direction speed to jumping tasks (Fousekis, Tsepis, & G, 2010; Lockie, et al., 2014; Bailey, Sato, Burnett, & Stone, 2015; Brown, et al., 2017; Arboix-Alió, et al., 2021). Furthermore, the asymmetries' association to reduced athletic performance has been researched but up to now, no final statement can be made, as some studies found a negative association (Raya-González, et al., 2020; Pardos-Mainer, et al., 2021), while others did not (Madruga-Parera, et al., 2020; Bishop, et al., 2021a). Finally, a major part of research on limb dominance and therefore inter-limb asymmetries is related with their connection to injuries (Helme, Tee, Emmonds, & Low,

2021). Do inter-limb asymmetries have a promoting effect on injuries? Up until now, research is trying to figure out the answer, making it a very recent question of sports research. Again, some studies have found a negative effect of asymmetries on the risk of injury (Smith, Chimera, & Warren, 2015; Steidl-Müller, Hildebrandt, Müller, Fink, & Raschner, 2018), while others did not (Beynnon, Renström, Alosa, Baumhauer, & Vacek, 2001; Chalmers, et al., 2018). Therefore, no conclusive statement can be made until further high-quality investigations clear the picture (Helme, Tee, Emmonds, & Low, 2021). In case inter-limb asymmetries lead to a higher risk of injury, methods must even more urgently be found to minimise asymmetries.

Additionally, to the best of the author's knowledge, research about sport specificity in inter-limb asymmetries is very rare. Only two studies could be found in which two sports were compared to each other, (1) basketball and handball and (2) basketball and soccer (Barrera-Domínguez, et al., 2021; Domínguez-Díez, et al., 2021). Overall, both showed no significant difference in asymmetries between the sports (Barrera-Domínguez, et al., 2021; Domínguez-Díez, et al., 2021). Nevertheless, two studies cannot provide a holistic picture about sport specificity in asymmetries, marking the purpose of this study: further investigation in asymmetries' sport specificity by comparing female soccer and floorball athletes. Neither of both before mentioned, similar studies focused on women. Though, female athletes are relevant, since a study by Costello et al. in 2014 stated that females are underrepresented in Sports and Exercise Medicine, even though the number of female athletes has grown exponentially since the release of Title IX of the Education Amendments Act of 1972 (Tanaka, LiBrizzi, Rivenburgh, & Jones, 2021). Literature also shows that female athletes present more prevalent lower limb asymmetries in strength, coordination and postural control than men (Myer, Brent, Ford, & Hewett, 2011).

Besides, soccer and floorball are relevant as both of them are multidirectional team sports, characterised by high-intensity unilateral actions such as changes of direction, which are likely to result in the athletes developing inter-limb asymmetries (Maloney, Richards, Nixon, Harvey, & Fletcher, 2017; Loturco, et al., 2019). Besides, team sport athletes typically use one limb more frequently than the other to achieve a better coordination, which can lead to a difference in the strength capacity between both limbs (Stephens, Lawson, DeVoe, & Reiser, 2007). However, in multidirectional sports it would be better to be equally efficient at changing directions in both legs, given the variable nature of agility requirements (Dos'Santos, Thomas, Jones, & Comfort, 2019).

Women's soccer continues to grow in popularity, worldwide and in Switzerland specifically, with a duplication in the number of women soccer academies from 2012 to 2017 worldwide and soccer

being the most participated team sport in Switzerland, presenting a number of 15'889 registered female youth soccer players (<18) in 2019 (Van Lange, et al., 2018; FIFA; UEFA). Floorball, a relatively new sport lacking scientific knowledge, has become very popular in Europe during the last decade with the largest member associations in Sweden, Finland, Switzerland, Czech Republic and Norway (Pasanen, Parkkari, Rossi, & Kannus, 2008b; Tervo & Nordström, 2014). In Switzerland, floorball has risen during the last 25 years to the third most played team sport (Zwahlen, Boss, Gisler, Spöring, & Sprecher, 2013).

With an increase in women's participation in these sports, so does the importance of scientific research about women's possible injury risk factors such as inter-limb asymmetries. In previous research the incidences of injuries in female athletes of both sports per 1000 hours of training and per 1000 hours of competition were widely ranged: in soccer 3.7-7 for training and 14.3-24 for competitive exposure and in floorball 1-2.5 for training and 15.9-40.3 for competitive exposure (Engström, Johansson, & Törnkvist, 1991; Wikström & Andersson, 1997; Ostenberg & Roos, 2000; Snellman, et al., 2001; Pasanen, et al., 2008a).

Considering the possible injury risk of inter-limb asymmetries, the current study aimed to identify sport specific differences in inter-limb asymmetries between youth female soccer and floorball players. The magnitude and direction of asymmetries were assessed using a test battery of six unilateral jumping tasks in horizontal and lateral direction. The direction of asymmetries indicates which leg performed better (the dominant or the non-dominant one) and unilateral jumps refer to jumps in which only one leg at a time is used.

The primary hypothesis was that overall, the magnitude of asymmetry would be higher for soccer players than for floorball players because while playing, soccer players do not perform the movement of kicking the ball with both limbs in equal amounts and asymmetries could therefore be expected (Hart, et al., 2016; Ade, Fitzpatrick, & Bradley, 2016; Bishop, et al., 2020).

Secondarily, the direction of asymmetries was expected to be fluctuating between the dominant and the non-dominant leg, showing a poor consistency between the jumping tasks like it was the case in previous studies (Madruga-Parera, et al., 2020; Arboix-Alió, et al., 2021).

Lastly, it was expected in both sports that the longer the athletes already practised their sport (referring to as playing time), the lower asymmetries would be detected. Previous research has highlighted this trend in inter-limb asymmetries focusing on strength (Fousekis, Tsepis, & G, 2010). To the best of the author's knowledge, no study has yet investigated the correlation of playing time and inter-limb asymmetries in jumping tasks.

2 Methods

The aim of this investigation was to detect sport specific differences in inter-limb asymmetries between youth female soccer and floorball players. The magnitude and direction of asymmetries were assessed using a specifically for the current study drawn up test battery of six unilateral jumping tasks in horizontal and lateral direction.

2.1 Participants

A total of 36 female youth team-sport players participated in this study. The subjects consisted of two amateur teams, one from soccer (U-19) and one from floorball (U-21). Both teams were competitionally active and trained multiple times a week. The soccer players ($n=18$, age: 16.7 ± 0.8 years, height: 1.63 ± 0.06 meters, weight: 58.9 ± 7.4 kg; training experience: 4.8 ± 3.4 years) trained two times a week, performing additional matches. The floorball players ($n=18$, age: 17.6 ± 0.9 years, height: 1.66 ± 0.05 meters, weight: 57.9 ± 6.5 kg; training experience: 8.6 ± 2.5 years) trained four times a week, also performing additional matches. The personal data are presented as means and standard deviations (means $\pm$ SD). For the comprehensive collection of both sports' personal data see attachments: *1 The participants' personal data*.

Goalkeepers were excluded from the final analysis due to their specific role (Raya-González, Clemente, & Castillo, 2021). Inclusion criterion required pain-free jumps: if an athlete felt upcoming pain, the tests were discontinued. Therefore, team members, who were injured at the time of the data collection, were also excluded from the tests.

The study was carried out under consent of the teams' training staff.

2.2 Design

The methodical design of this study was based on a previously performed pilot project taking place in autumn 2021 (see attachments: *2 Poster: Pilot project*). Therefore, the study profited from improved details, especially in the fields of logistics, organisation and communication.

The data collection of this study was accomplished between March and May in 2022 during multiple sessions in team trainings and outside the trainings. The tests took place on the team's usual training surface, thus on artificial turf with the soccer team and on gym floor with the floorball team. All tests were conducted by the author herself and her assistant. The participants filled out a

baseline questionnaire about their personal data (including age, height, weight, years of training experience and leg dominance) in order to characterize both groups. The dominant leg was in both groups defined as the leg that kicks a ball (van Melick, Meddeler, Hoogeboom, Nijhuis-van der Sanden, & van Cingel, 2017).

Before starting the tests, the participants had to do a warm-up (within the context of training or by themselves), they were just told to feel ready for explosive jumps. The test subjects received verbal instructions about how to perform the jumps. They were not told about the final goals of this research regarding inter-limb asymmetries in order to prevent an interference with the results.

To be responsive to the athletes' moving patterns while performing their sport, a test battery consisting of six jumps was drawn up. The participants performed the tests in groups of one to three. They were allowed to do one practise trial with each leg for every jump to get a feel for the movement before two valid trials per limb were measured (Lambert, et al., 2020). Of those the better one was included into statistical analysis according to Mortaza et al., who introduced a scoring system for athletic competitions where the best trial is seen as the final score (Mortaza, et al., 2012).

2.3 Procedures

The specifically drawn up test battery focused on being responsive to both soccer's and floorball's moving patterns. Hence, only horizontal jumps were included in the battery. No vertical jumps were performed because in soccer as well as in floorball, vertical jumps are not part of the characteristic movements. But to accelerate, reverse or change direction quickly and effectively and then reaccelerate are important features in many team sports, including soccer and floorball (Thomas, Comfort, & Jones, 2018; Pereira, et al., 2018). In these kinds of sports, the majority of high-intensity actions occur unilaterally (Gonzalo-Skok, et al., 2016; Bishop, et al., 2021b). Therefore, the whole test battery consisted of unilateral jumps, meaning jumps with only one leg at a time.

To reach sport specific conditions for soccer and floorball within the test battery, all participants were tested with their normally used footwear and had to perform the jumping tasks on their sport specific surface, artificial turf for soccer and hall floor for floorball respectively (Lambert, et al., 2020).

The order of the tests was in the following way: (1) *Single Leg 6-meters timed Hop*, (2) *Single Leg Hop for Distance*, (3) *Single Leg Hop for Distance – new version*, (4) *Single Leg Triple Hop*, (5) *Single*

Leg Crossover Hop, (6) *Single Leg Side Hop*. To minimize the influence of fatigue, the *Single Leg 6-meters timed Hop* was performed at the beginning because springiness was needed. The *Single Leg Side Hop* was put to the end as the participants were exhausted afterwards.

For each jump the examiners demonstrated the procedures to the participants and made sure that there was no misunderstanding. All subjects were allowed to start with their preferred leg. The examiners decided in real-time whether all criteria to carry out the jump correctly were fulfilled and the jump therefore valid or invalid. The participants were allowed to perform as many trials needed to accomplish two valid trials per limb for every jump.

2.3.1 Single Leg Hop for Distance (SLHD)

The Single Leg Hop for Distance (SLHD; see chapter 9: *Index of Abbreviations*), shown in Figure 1a, is proven to be a valid and reliable test to access muscle strength and power deficits (Reid, Birmingham, Stratford, Alcock, & Giffin, 2007; Kockum & Heijne, 2015; Dingenen, Truijen, Bellemans, & Gokeler, 2019). It is recommended in clinical such as sport practice as it is possible to detect injury risks for lower back and lower extremity in competitive athletes by assessing inter-limb asymmetries (Munro & Herrington, 2011; Brumitt, Heiderscheit, Manske, Niemuth, & Rauh, 2013). The participants were instructed to stand on one leg right behind the starting line, touching the line with their toes. Their goal was to jump as far as possible by taking off and landing on the same foot with their hands on their hips. Subsequently to the landing, balance had to be maintained for at least three seconds before placing the opposite foot on the floor. The hop distance was measured in centimetres (cm) with measuring tape fixed on the floor, considering the distance from the starting line to the participant's heel where the landing took place. A trial was considered unsuccessful in case of the following criteria: (1) leaving the hands from the hips; (2) not maintaining balance for three seconds (including multiple jumps at landing or supporting the balance with the other foot or the hands); (3) swinging the opposite leg before taking off to gain momentum (Scinicarelli, Trofenik, Froböse, & Wilke, 2021). It was allowed to bend the knee of the tested leg before taking off in order to be able to jump with more strength.

2.3.2 Single Leg Triple Hop (SL-Triple)

The *SL-Triple* (Figure 1d) is a commonly used reliable jump test with excellent test-retest reliability, meaning the consistency of results when repeating the test on the same sample at a different point in time (Risberg, Holm, & Ekeland, 1995; Dingenen, Truijen, Bellemans, & Gokeler, 2019; Munro & Herrington, 2011). To perform the SL-Triple, the initial situation, the validity criteria, the measuring

technique and the goal to jump as far as possible are the same as for the SLHD. The only difference to the *SLHD* is that for the *SL-Triple* three consecutive jumps had to be accomplished instead of one. Of the three jumps only on the third and therefore last one the balance had to be maintained for three seconds, the first jumps had to be carried out without a halt between them.

2.3.3 Single Leg Crossover Hop (*SL-Crossover*)

The *SL-Crossover* (Figure 1e) is shown to display good to excellent test-retest reliability (Munro & Herrington, 2011; Madsen, Booth, Volz, & Docherty, 2020). Like for the *SL-Triple* the participants were instructed to perform three consecutive jumps. This time though, they had to perform the hops over a 15-cm-wide mark of tape. The goal was still to jump as far as possible while maintaining balance on the third hop. The initial situation, validity criteria and measuring technique are again according to the SLHD.

2.3.4 Single Leg Hop for Distance – new version (*SLHD-new*)

Specifically for this study, a new variant of the *SLHD*, the *SLHD-new* (Figure 1b), was designed. As one of the original validity criteria was maintaining balance for three seconds, the participants had to jump with caution in order to manage a stable landing. Therefore, they restricted themselves and didn't use their full performance capability. To avoid that and receive the results out of the jumping ability only, the *SLHD-new* was built up the exact same principles as the *SLHD* but without maintaining balance at the landing.

2.3.5 Single Leg 6-meters timed Hop (*SL-6m-timed*)

For the *SL-6m-timed* (Figure 1f), a reliable test (Booher, Hench, Worrell, & Stikeleather, 1993; Munro & Herrington, 2011), the participants were instructed to hop a marked distance of 6 meters on one leg as fast as possible. The time was measured by light barriers (TCi System by Brower Timing Systems) placed at the starting and finishing line. All subjects were told to start about half a meter behind the starting line so that the first light barrier was not triggered too early and to slow down only after the second light barrier. This time, both arms were free to use with the aim to achieve a natural flow of movement. Swinging the opposite leg before taking off to gain momentum was not allowed.

2.3.6 Single Leg Side Hop (*Side-Hop*)

The *Side-Hop* (Figure 1c) is a valid and reliable jump test to assess knee function through strength resistance under influence of fatigue through controlled, fast and repetitive lateral jumps

(Gustavsson, et al., 2006; Kockum & Heijne, 2015). The subjects were told to jump sideways on one leg over two parallel lines, marking a distance of 40 centimetres. The goal was to perform as many jumps as possible in 30 seconds. The start was next to one of both lines, standing on one leg. To facilitate body balance, free arm movement was allowed.

The following criteria was used to discard invalid jumps: (1) jumping on the marked line with the tested leg; (2) performing double/ multiple jumps and (3) supporting the landing with the opposite leg. The number of successful jumps (score= total jumps – invalid jumps) was counted according to Scinicarelli et al. in real-time by the examiner (Scinicarelli, Trofenik, Froböse, & Wilke, 2021).

Other than for the other jumps, no full practise trial was advised due to upcoming fatigue. However, the participants were advised to perform some jumps over the marked lines to get a feel for the distance.

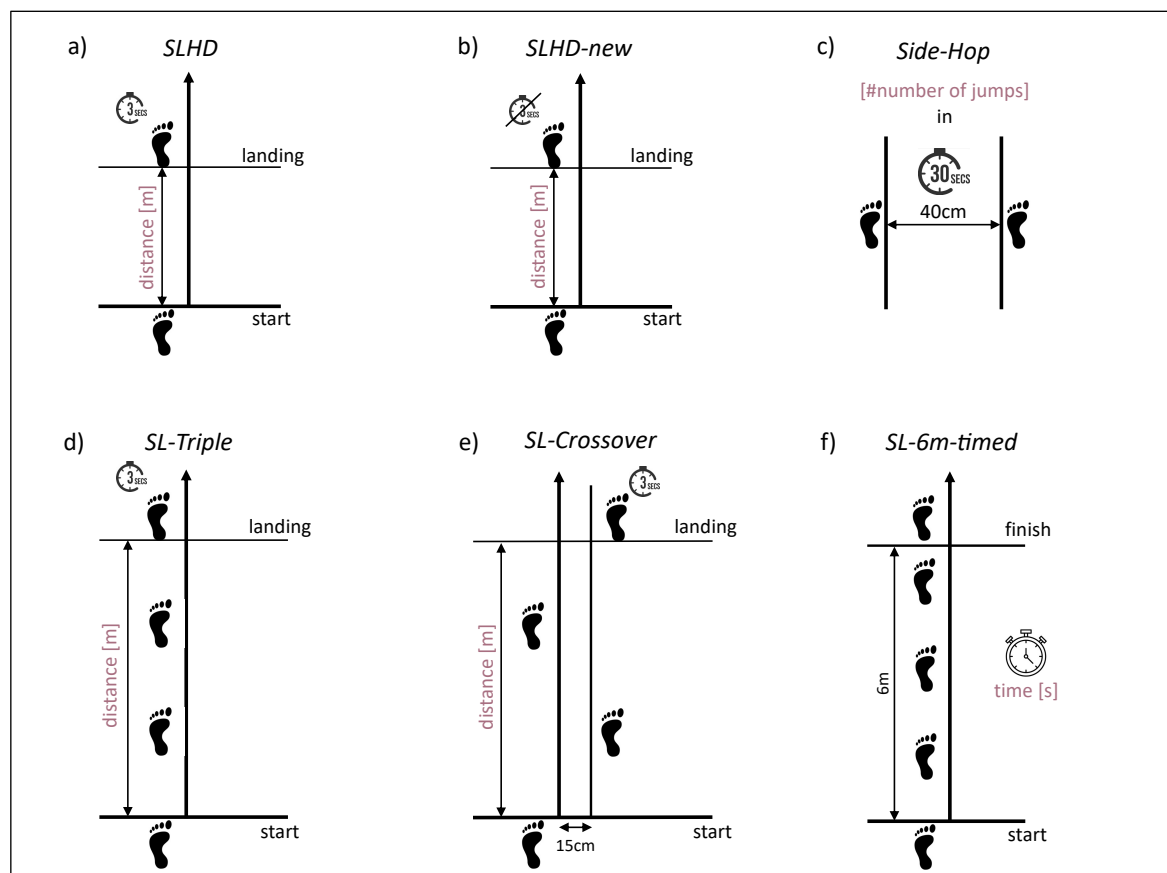


Figure 1: Test battery

1a) Single Leg Hop for Distance (SLHD) **1b)** Single Leg Hop for Distance - new version (SLHD-new) **1c)** Single Leg Side Hop (Side-Hop) **1d)** Single Leg Triple Hop (SL-Triple) **1e)** Single Leg Crossover Hop (SL-Crossover) **1f)** Single Leg 6-meters timed Hop (SL-6m-timed)

This figure shows the specifically for this study drawn up test battery to assess lower inter-limb asymmetries. The battery consisted of 6 unilateral jumping tasks in horizontal and lateral direction.

The testing order of the jumps was the following: (1) SL-6m-timed, (2) SLHD, (3) SLHD-new, (4) SL-Triple, (5) SL-Crossover, (6) Side-Hop.

2.4 Statistical Analysis

Data processing and data visualization were performed using Microsoft Excel. For final statistical analyses, the data was imported into the statistical program R (The R project for statistical analysis, version 4.0.3, see attachments: *3 Details about the statistical software*).

Personal data are presented as means and standard deviations (mean $\pm$ SD).

For each participant all jumping scores were recorded as distance (centimetres) or time (seconds). Based on this data, for each participant the Limb Symmetry Indexes (LSI) were calculated for every jump test. These interlimb asymmetries were quantified as percentual differences between both lower limbs, using a formula proposed by Bishop et al. (Bishop, Read, Chavda, & Turner, 2016). With this formula, it was possible to assess the direction of asymmetry. If the dominant limb (DL), defined as the leg that is used to kick a ball (van Melick, Meddeler, Hoozeboom, Nijhuis-van der Sanden, & van Cingel, 2017), accomplished a better score, the LSI was positive. Otherwise, if the non-dominant limb (NDL) scored higher, the LSI was negative. The NDL was defined as the leg usually not kicking a ball. Assessing not only the magnitude but also the direction of asymmetry is important as the better performing limb is not consistently the dominant or the non-dominant one (Madruga-Parera, et al., 2020; Arboix-Alió, et al., 2021).

The formula for the LSI:

$$LSI = (1 - NDL/DL) \times 100$$

For the SL-6m-timed hop (measured in seconds) a faster result, i.e., fewer seconds, is the better one. Therefore, the formula had to be modified in order to still get a positive value if the DL performed better than the NDL:

$$LSI_{(SL-6m-timed)} = (1 - DL/NDL) \times 100$$

This way, the magnitude and the direction of asymmetries could be calculated for every jump. The statistical analysis was therefore divided into two parts: into the directional asymmetries and the absolute asymmetries (the magnitude of directional asymmetries).

The directional asymmetries were normally distributed while the absolute asymmetries were strongly right skewed and therefore showed no normal distribution. A normal distribution (also known as Gauss distribution) means that all data are distributed evenly around the mean (which is at the same time the median), creating a symmetrical graph. Right skewed means that the data are

not normally distributed, instead the median is smaller than the average, resulting in an at first steeply ascending and later slowly flattening graph.

The distribution of data was evaluated qualitatively based on the histograms. For the directional asymmetries, the data were subsumed using the average, whereas for the absolute asymmetries, data were subsumed using the median because of the skewed data distribution.

To estimate how asymmetry is influenced by sports and different jumps, a linear mixed effect (LME) model using function lmer in program R was applied for the statistical analysis. As the LME model requires a near normal error distribution to become interpretable, the absolute asymmetry values were transformed by the square root in order to get rid of the right skewed distribution (see attachments: *4 Normal data distribution through square-root-transformation*). The variables 'sports' and 'jumps' were included as fixed effects and the variable 'subject' was included as random effect into the model. This statistical model allows to estimate and correct for individual subject specific random effects present in the error distribution, thereby increasing the accuracy of estimated variables.

To note, the results of the LME model are comparable to the estimates computed by a 2x6 ANOVA including only the variables sports and jumps as fixed effects. This indicates that the inter-variability between subjects and the intra-variability within subjects are of similar amplitude.

The criterion for statistical significance was set at $p \leq 0.05$. In the diagrams significance was expressed with stars, dependent on the height of p-values: *** < 0.001, ** < 0.01, * < 0.05.

By implementing the LME (and ANOVA) model in the program R, the statistical analysis was strongly supported by Dr. sc. techn. Andreas Steingötter.

3 Results

Focusing on sport specific differences, this study assessed the magnitude and direction of lower inter-limb asymmetries in youth female soccer and floorball players. To do so, a test battery of six unilateral jumping tasks in horizontal and lateral direction was used.

Comprehensive tables of jump lengths, absolute and directional asymmetries can be found for both sports in the attachments (*5 Tables of jump lengths and asymmetries*).

3.1 Effect of sports

3.1.1 Total effect of sports

All calculated LSIs of the 6 jump types for each participant of both sports are presented in *Figure 2*. For the absolute values a right skewed distribution for both sports can be detected in *Figure 2ac*. The linear mixed effect (LME) model reveals a significant difference above all jumps between the absolute values of both sports ($p=0.0067$). Soccer's mean absolute asymmetry is 7.3%, while floorball shows a mean of 5.4%, resulting in a difference of 1.9% on average.

The directional asymmetries are normally distributed (*Figure 2bd*) with averages for both sports slightly over 0 (*Figure 2d*), indicating an overall slightly better but not significant performance with the dominant leg. No significant differences were found for the directional asymmetries between the sports.

Remarkable is the visible difference in dispersion of data in the *Boxplots 2cd*, showing a narrower, even though not significantly different dispersion for floorball than for soccer.

3.1.2 Effects of sports within the jump types

Differences of sports within the jump types are shown in *Figure 3*. Since the LME detected no significant interactions between the sports and the jumps, the following results are all non-significant. Instead, they are observations that can be made by looking at the diagrams.

For the absolute values, the soccer team displays a wider distribution with higher medians for every jump except for jump type 2, for which the opposite is the case (*Figure 3a*).

The directional values show in general a dispersion balanced around 0 (*Figure 3b*). Having a closer look, special cases are the jumps 3, 4 and 6. In jump 3, both sports demonstrate a tendency towards the positive range with more than 75% of data over 0. Jumps 4 and 6 show variations between the sports regarding the direction of dispersion. Especially jump 4 for the soccer team is remarkable, presenting a strong tendency towards the negative range.

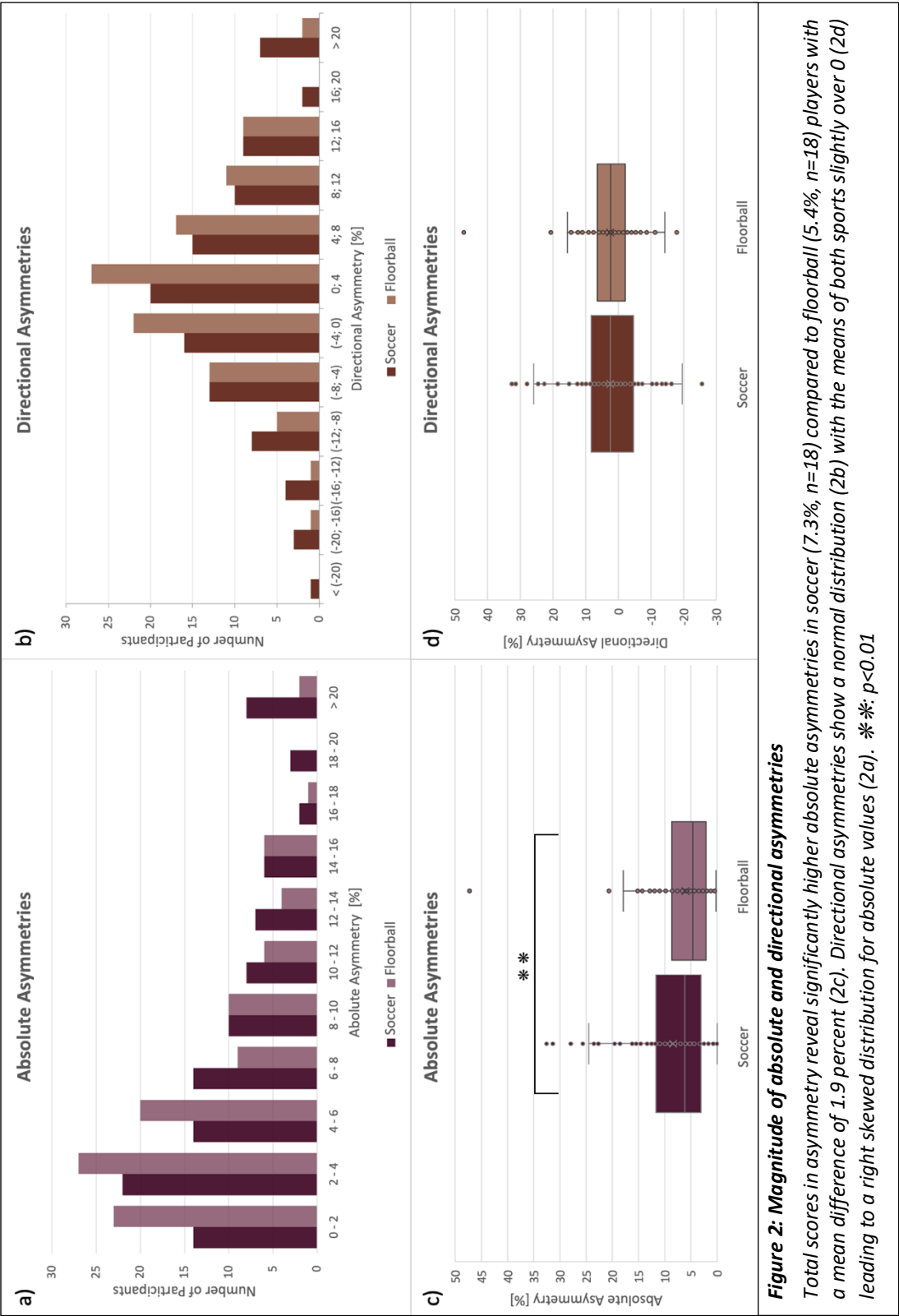
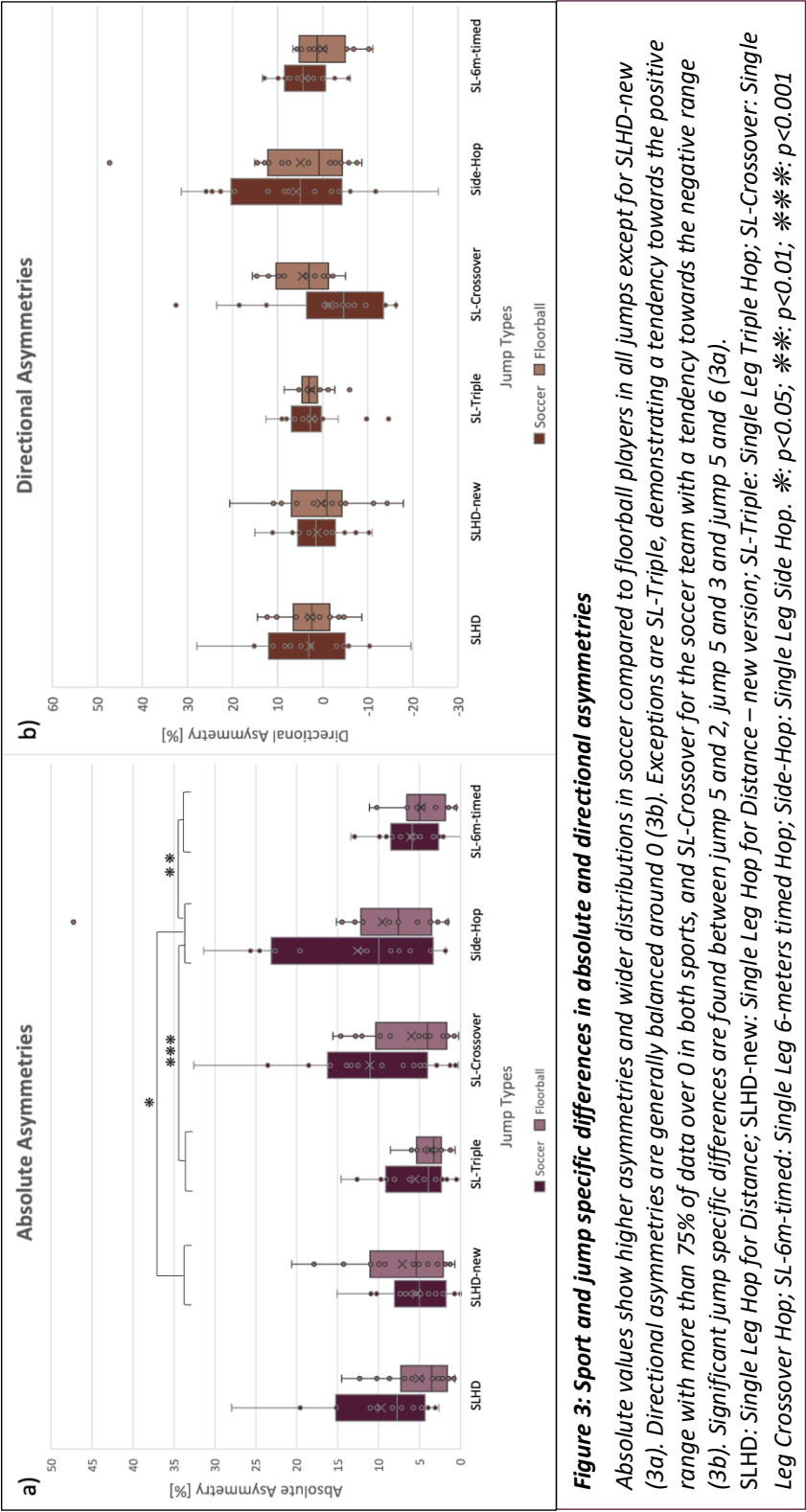


Figure 2: Magnitude of absolute and directional asymmetries
Total scores in asymmetry reveal significantly higher absolute asymmetries in soccer (7.3%, n=18) compared to floorball (5.4%, n=18) players with a mean difference of 1.9 percent (2c). Directional asymmetries show a normal distribution (2b) with the means of both sports slightly over 0 (2d) leading to a right skewed distribution for absolute values (2a). ***: p<0.01



3.2 Effects of jump types on asymmetries

To evaluate the general effects of the different jump types on inter-limb asymmetries, in the data no differentiation between sports was made.

For absolute values, jump 5 is the jump with the highest detected asymmetry (on average 10.4%), while jump 3 is the one with the lowest (on average 4.75%). Ranking the jump types by increasing effects on the absolute asymmetries, the following results were found: 3<6<2<4<5. Significant differences between the absolute values of the jump tests were revealed by a post-hoc analysis to detect pairwise differences between the jump types. Jump 5 showed significantly higher asymmetries than jump 2 ($p=0.013$), 3 ($p<0.001$) and 6 ($p=0.006$).

No significant effects of the jump types were found when analysing the directional asymmetries. The dispersions of the jumps were balanced around 0 with the exception of jump 3, ranging mainly over 0.

3.3 Asymmetry and personal data

As a part of the statistical analysis, interactions between the personal data (including age, height, weight and years of training experience) and the detected asymmetries were analysed. For both absolute and directional values, no significant interaction with personal data was detected.

The correlation between asymmetry and training experience was evaluated furthermore, again showing no significant correlation with $r^2= 0.0199$ for soccer and $r^2= 0.0009$ for floorball (see attachments: 6 *Non-significant correlation between training experience and asymmetry*).

4 Discussion

This study aimed to detect sport specific differences in inter-limb asymmetries between youth female soccer and floorball players. The magnitude and direction of asymmetries were assessed using a test battery of six unilateral jumping tasks in horizontal and lateral direction. The main novelty of this study was comparing a well-researched sport like soccer to a sport we generally lack scientific knowledge about (Tervo & Nordström, 2014). To the best of the author's knowledge, no study has yet investigated young female floorball players' inter-limb asymmetries.

This investigation's outcome measures were the inter-limb asymmetries of every participant for each jump. The hop distances were directly calculated into asymmetries, without comparing the distances themselves, as there would have been too many external influences. Aiming maximal sport specification, all athletes performed the tests on their usual training surface, thus the floorball team on gym floor indoor and the soccer team on artificial turf outdoor, adding the factor wind. Additionally, all athletes wore their normally used footwear. Considering these factors, comparing hop distances would have led to unreliable results through too much external influence. However, by only comparing the inter-limb asymmetries, all these factors become irrelevant as all athletes had the same preconditions for both legs.

4.1 Interpretative Approaches

Based on the concept of this Matura work, assessing magnitude and direction of inter-limb asymmetries, two main results were found: the first one regarding the asymmetries' magnitudes and the second one regarding their direction. For the first main result, this study indicates a significant difference above all jumps between the magnitudes of asymmetries for both sports, supporting the study's main hypothesis. As for the second main result, the findings imply that leg dominance has in general no impact on asymmetries like it was expected in the second hypothesis.

Through detecting a significant difference between the height of the asymmetries in both sports, the deduction that asymmetries are sport specific is standing to reason. Though, this conclusion disagrees with the findings of the only two similar studies found, comparing jumping-based asymmetries in soccer and basketball and in basketball and handball respectively (Barrera-Domínguez, et al., 2021; Domínguez-Díez, et al., 2021). In the mentioned study no significant overall difference in asymmetries between both sports was detected (Barrera-Domínguez, et al., 2021; Domínguez-Díez, et al., 2021). However, to the best of the author's knowledge, the current work is

the first to compare inter-limb asymmetries in soccer and floorball. Based on the finding of this study, the sport specific nature of jumping-based inter-limb asymmetries can be suggested but needs further investigations as support.

This difference between both sports can be explained through the variable nature of floorball regarding the standing leg. Different shooting and passing situations ask for variable roles of the standing leg. Therefore, there cannot be a huge difference between both legs. The asymmetry in floorball players is to be expected mainly in the upper body because of the steady stick side of the floorball stick. Soccer players, on the contrast, are unlikely to kick the ball in equal amounts with both legs, why inter-limb asymmetries can be expected (Hart, et al., 2016; Ade, Fitzpatrick, & Bradley, 2016; Bishop, et al., 2020). Another possible explanation could be that the floorball players train additionally to the team trainings one to two times per week in a fitness studio with physio therapists establishing their training program the same for both legs. For the floorball players, working out in the gym functions therefore as a compensatory training reducing asymmetries (Clijisen & Hohenauer, 2022). Lastly, repeated jumps can lead to inter-limb asymmetries, as most athletes have a takeoff leg with which they prefer to push themselves off the ground (Domínguez-Díez, et al., 2021). While floorball does not include any kind of jumps, soccer players jump regularly to gain height to do headers. Therefore, the occurrence of jumping might also lead to the enhanced asymmetries among the soccer team in comparison to the floorball team.

Furthermore, a remarkable difference in the asymmetries' dispersion between both sports can be observed (Figure 2cd). The floorball team displays a clearly visible narrower dispersion than the soccer team. An approach standing to reason would be the fact that the floorball team trains two more times per week and its participants practise the sport in average nearly four years longer than the players of the soccer team. This leads to the floorball team being a more homogeneous group compared to the soccer team.

In this study, the participants' asymmetries rarely favoured the same side (direction of asymmetry) between the jump types. This finding is in line with previous studies, in which Kappa coefficients were calculated to determine how consistently asymmetries favour the same side between tests (Madruga-Parera, et al., 2020; Arboix-Alió, et al., 2021). Kappa values were interpreted according to the suggestions from Viera and Garret (2005), meaning ≤ 0 = poor, 0.01-0.20 = slight, 0.21- 0.40 = fair, 0.41-0.60 = moderate, 0.61- 0.80 = substantial, and 0.81-0.99 = almost perfect. The study from Arboix-Alió et al. (2021) detected poor to fair levels of side consistency, while Madruga-Parera

et al. (2020) even found only poor to slight agreements. Further support provided Bishop et al. (2021b) who used the Kappa coefficient to examine the side consistency of peak force asymmetries. Considering the own findings and the ones of the previous studies it can be suggested that asymmetries are on the one hand highly variable and task-specific (Madruga-Parera, et al., 2020; Raya-González, Clemente, & Castillo, 2021). On the other hand, this investigation suggests that jumping-based inter-limb asymmetries may not be leg dominance dependent. While the dominance of a limb is associated with better skills in mobility, coordination and motor function, one cannot necessarily assume the same for strength (Clijsen & Hohenauer, 2022).

However, the determination of the dominant leg should be questioned critically. Unlike the study by Melick et al. that used a whole questionnaire to define the dominant leg, this study narrowed down the questions to the most reliable one (leg to kick a ball). Using the whole questionnaire could however provide a bigger picture regarding leg dominance.

In line with previous research, the magnitude of asymmetry values varied between the jumping tests, reinforcing the task-specific nature of inter-limb asymmetries (Madruga-Parera, et al., 2020; Arboix-Alió, et al., 2021; Fort-Vanmeerhaeghe, Bishop, Buscà, Vicens-Bordas, & Arboix-Alió, 2021; Raya-González, Clemente, & Castillo, 2021).

This task-specific nature of asymmetries explains the detected differences between the effects of jump types, of which three were significant ($5>2$, $5>3$, $5>6$).

Therefore, these findings highlight the importance of a broad test battery to achieve measurements on a variety of skills instead of relying on an only jumping test to assess inter-limb asymmetries (Arboix-Alió, et al., 2021).

The differentiation between sports within the jump types shows that soccer displays in general higher asymmetries than floorball (*Figure 3ac*). The only exception marks jump 2 (*SLHD-new*), a self-created new variant of the *SLHD*. As for the original *SLHD* one of the validity criteria was maintaining balance for three seconds, the participants had to jump with caution in order to manage a stable landing. Therefore, they restricted themselves and did not use their full performance capability. To avoid that and to receive the results out of the jumping ability only, the *SLHD-new* was built up the same as the *SLHD* but without maintaining balance at the landing. However, this new variant is not recommended to use in further investigations. By quitting the stable landing, participants were able to adapt the jump better to their individual jumping technics. This led to a lack of standardisation, whereby the *SLHD-new* was more sensitive to individual jumping technics instead of detecting

asymmetries. Based on these conclusions, the *SLHD-new* is suggested to be a non-reliable jump test to assess inter-limb asymmetries. Therefore, its results contrary to the other findings in this study are relativised.

Although statistically not significant, further remarkable abnormalities can be observed when looking on the effects of sports within the jump types on the directional asymmetries (*Figure 3b*). Reasons for the abnormalities remain speculative based on the measurements within this study.

Jump 3 (*SL-Triple*) shows a tendency towards the positive range with more than 75% of data over 0 for both sports, meaning that more than 75% of the participants performed better with their dominant limb. This could be explained by the fact that the *SL-Triple* is the only jump in this battery that displays a leg dominance dependency for both sports. However, this is a vague speculation, and the reason why remains unclear.

In jumps 4 and 6, the *SL-Crossover* and the *SL-6m-timed* hops, variations between the sports regarding the direction can be observed (*Figure 3b*). For the *SL-6m-timed* hop no explanation was found. However, the strong tendency towards the negative range in the *SL-Crossover* hop among the soccer team indicates a leg dominance dependence with the non-dominant limb as the better-performing limb. That can be explained by the most prevalent of soccer's game-based activities, the kicking skill (Ball, 2013; Hart, et al., 2016). While the kicking limb (dominant limb) kicks the ball, the support limb (non-dominant limb) has to forcefully provide stability, balance and support (Hart, et al., 2016). These three are all abilities needed for the *SL-Crossover*. Additionally, before kicking a ball, the support leg performs a diagonally sideways shifted step, a movement that can also be compared to the *SL-Crossover*. Given these similarities, it makes sense that the soccer players showed a tendency towards the negative range in the directional asymmetries of the *SL-Crossover*, meaning that they performed better with the non-dominant and therefore support limb.

The aforementioned leg-to-leg asymmetry in the kicking movement while playing soccer is also thought to be responsible for the high asymmetries detected in the Side-Hop among the soccer team. One of the main features for this jump is sideways balance. When soccer players want to kick a ball, there comes a moment when the player stands only on the NDL while the DL builds up momentum for the kick (Hart, et al., 2016). During this moment the NDL has to balance out the movement and can therefore generally be expected to display greater sideways balance compared to the DL, presenting a source of inter-limb asymmetry.

In contrast, floorball is characterised through perpetual stop-and-goes, which require both legs equally to perform sudden changes of direction like it is the task in the Side-Hop.

Considering both aspects, it comes as no surprise that the soccer players presented higher values of asymmetry in the Side-Hop than the floorball players.

In this study, no interactions between asymmetry and personal data were found. For age, weight and height this can be explained by the fact that these factors are always the same for both legs and therefore not leading to asymmetries. However, contrary to this study's hypothesis, again no correlation was found between asymmetry and training experience. The most logical approach to explain this finding is that the years of training experience differed too much, allowing no trend to be found (see attachments: *6 Non-significant correlation between training experience and asymmetry*).

4.2 Limitations and Strengths

Some limitations should be considered when interpreting this study's findings. Firstly, the two groups, referred to as soccer and floorball team, didn't have the exact same preconditions. On average, the athletes of the floorball team were about a year older and had nearly about 4 years more training experience. Secondly, with 18 subjects per group generalisations should be made with caution. More test subjects would therefore lead to a more generally valid result. Though, in the context of a Matura work, that was not the aspiration. Thirdly, the influence of fatigue could not be avoided, as in both teams some participants were tested in the beginning of a training while others only towards the end of it. Lastly, a planned, so-called Tapping-Test could not be performed, meaning the loss of an additional value. It foundered on financial means (the school only has an inapt force place) and borrowing one was not possible because of personal details on the linked program.

Still, the current study has its strengths to value highly. Firstly, the specifically drawn up test battery was based on lots of scientific research. The goal was to be the most responding possible to the athletes' moving patterns while performing their sport. Through the broad variety of jumps, many requirements were met, including explosibility, stability, strength, multidirectional movement, acceleration, coordination and stamina. Secondly, suitable professional statistical analyses were performed. This way, not only qualitative but also quantitative analyses were carried out, which are visualised by comparing diagrams. Thirdly, the last strengths lie in the selected group of partitioners. Literature shows that female athletes, who are not as much the subjects of scientific research in soccer as males, present more prevalent lower limb asymmetries in strength,

coordination and postural control (Myer, Brent, Ford, & Hewett, 2011). Previous research did also ask specifically for further studies to investigate females' asymmetries (Dingenen, Truijen, Bellemans, & Gokeler, 2019). Additionally, inter-limb asymmetries in female athletes playing floorball, a in Europe fast-growing team sport lacking scientific knowledge, poses new paths for future investigations (Pasanen, Parkkari, Rossi, & Kannus, 2008b).

4.3 Outlook

Other than that, future investigations are advised to focus on standardising test protocols for common unilateral jump tests to facilitate comparison between studies (Dingenen, Truijen, Bellemans, & Gokeler, 2019). Vast differences exist for example in measurement guidelines, instructions like arm positioning, the number of practise trials and, most important, in the calculations of asymmetries (Bishop, Read, Chavda, & Turner, 2016; Dingenen, Truijen, Bellemans, & Gokeler, 2019).

It would also be interesting to compare asymmetric sports with unilateral movements to a more symmetric sport in order to highlight the naturally existing asymmetries in all athletes without an asymmetric impact. Cyclic sports such as cross-country skiing, inline skating, running, or cycling would be good options (Clijsen & Hohenauer, 2022). That was originally an idea for this study but unfortunately it couldn't be realised because of logistic and temporal reasons; it would have gone beyond the constraints of a Matura work.

Aiming to further investigate the injury risk of sport specific interlimb asymmetries, future studies are advised to assess asymmetries in different sports and subsequently report all lower limb injuries experienced by study participants. Doing so, the studies could investigate sport specific asymmetries and the specific injury risk they pose on athletes. This study first intended to report acquired injuries but failed to present reliable reports because of poor data quality and the time-wise limited extent of this study.

Considering the possibly reduced abilities of athletic performance and increasing injury risk, further research of inter-limb asymmetries in uninjured athletes, predominantly females, and in all kinds of sports is still required to provide a holistic picture showing the effects of asymmetries on sports and vice versa (Raya-González, et al., 2020; Pardos-Mainer, et al., 2021; Helme, Tee, Emmonds, & Low, 2021).

5 Conclusion

This study aimed to detect sport specific differences in inter-limb asymmetries between youth female soccer and floorball players. The magnitude and direction of asymmetries were assessed using a test battery of six unilateral jump tasks.

In this study soccer appears to be a more asymmetric sport than floorball. Over the whole test battery, a significant difference of lower inter-limb asymmetries between the sports was detected. Additionally, asymmetries varied between different jump types for both sports, indicating that asymmetries may not only be sport specific but also task specific. Consequently, a broad test battery is suggested.

Given that asymmetries rarely favoured the same direction between jump types, no significant dependence of leg dominance was found for both sports. This suggests that leg dominance by itself is not to hold to account for asymmetries.

However, these results should be considered with caution as further research is required and demanded to provide a holistic picture and to support this study's findings, especially when considering the possibly reduced athletic performance abilities and increasing injury risk through asymmetries (Raya-González, et al., 2020; Pardos-Mainer, et al., 2021; Helme, Tee, Emmonds, & Low, 2021).

Sports-related accident costs are rising, female participation in sports continues to grow worldwide like it is the case for soccer, and floorball is gaining popularity in Europe and specifically in Switzerland rapidly (Pasanen, Parkkari, Rossi, & Kannus, 2008b; Zwahlen, Boss, Gisler, Spöring, & Sprecher, 2013; Van Lange, et al., 2018; Sammelstelle für die Statistik der Unfallversicherung UVG, 2020; Tanaka, LiBrizzi, Rivenburgh, & Jones, 2021). Therefore, it is pivotal to get the current knowledge about inter-limb asymmetries and how to reduce them to the athletes themselves, to the females as well as the males.

6 Practical Applications

Focusing on sport specific differences, the magnitude and direction of inter-limb asymmetries in youth female soccer and floorball players were assessed.

In line with previous investigations, the current study suggests monitoring inter-limb asymmetries in team sports (Madruga-Parera, et al., 2020; Arboix-Alió, et al., 2021; Raya-González, Clemente, & Castillo, 2021). Strength and conditioning coaches should focus on reducing asymmetries and, thus decreasing the potential associated risk of injury and the probability of reduced physical performance (Madruga-Parera, et al., 2020; Arboix-Alió, et al., 2021; Bishop, et al., 2021a; Raya-González, Clemente, & Castillo, 2021). To do so, previous research has already elaborated strength and stability exercises (Gonzalo-Skok, et al., 2016; Bishop, Turner, & Read, 2018c; Gonzalo-Skok, Moreno-Azze, Arjol-Serrano, Tous-Fajardo, & Bishop, 2019). With a selection of those exercises, a training routine was created and depicted on a poster to be hung up in sports halls and fitness studios. The intention was to reach athletes and get the exercises into their practise, considering the possible injury risk and reduction of athletic performance because of asymmetries (Raya-González, et al., 2020; Pardos-Mainer, et al., 2021; Helme, Tee, Emmonds, & Low, 2021).

VERMEIDE VERLETZUNGEN

Asymmetrien zwischen beiden Beinen als Verletzungsfaktor

- Die Asymmetrie meint den prozentualen Unterschied zwischen beiden Beinen bei Übungen zur einbeinigen Leistungserfassung.
- Eine erhöhte Asymmetrie zwischen den beiden Beinen kann leistungsvermindernd wirken und ein erhöhtes Verletzungsrisiko darstellen.
- Studien haben gezeigt, dass einbeiniges Krafttraining und Stabilisationstraining zur Reduktion von Asymmetrien führt.



mit Kettleballs, Kurz- oder Langhanteln
Bulgarian Split Squats
3x6 pro Bein, Gewicht individuell



Hände in die Hüfte
horizontale Einbeinsprünge
(3x4 pro Bein)



Hände in die Hüfte
vertikale Einbeinsprünge
(2x5 pro Bein)



Hände in die Hüfte
Drop Jumps
(2x5 pro Bein)



Squats auf instabiler Unterlage -> Bosu
(3x10)



mit leichtem Gewicht
einarmiges Armheben im Einbeinstand auf dem Bosu
(3x10 pro Seite)

Was du tun kannst: Ausgleichsübungen

Extrakt einer Maturaarbeit von Meret Güttinger, Bündner Kantonsschule Chur
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Figure 4: Informative poster with a training routine to reduce lower inter-limb asymmetries
This poster consists of 6 strength and stability exercises to reduce asymmetries. It was created with the aim to reach athletes and get the exercises into their practise.

7 References

- Ade, J., Fitzpatrick, J., & Bradley, P. (2016). High-intensity efforts in elite soccer matches and associated movement patterns, technical skills and tactical actions. Information for position-specific training drills. *J Sports Sci*.
- Afonso, J., Bessa, C., Pinto, F., Ribeiro, D., Moura, B., Rocha, T., . . . Clemente, F. (2020). *Asymmetry as a Foundational and Functional Requirement in Human Movement: From Daily Activities to Sports Performance*. Springer Nature.
- Arboix-Alió, J., Bishop, C., Benet, A., Buscà, B., Aguilera-Castells, J., & Fort-Vanmeerhaeghe, A. (2021). Assessing the Magnitude and Direction of Asymmetry in Unilateral Jump and Change of Direction Speed Tasks in Youth Female Team-Sport Athletes. *J Hum Kinet*.
- Bailey, C., Sato, K., Burnett, A., & Stone, M. (2015). Force-production asymmetry in male and female athletes of differing strength levels. *Int J Sports Physiol Perform*.
- Ball, K. (2013). Loading and performance of the support leg in kicking. *J Sci Med Sport*.
- Barrera-Domínguez, F., Carmona-Gómez, A., Tornero-Quiñones, I., Sáez-Padilla, J., Sierra-Robles, Á., & Molina-López, J. (2021). Influence of Dynamic Balance on Jumping-Based Asymmetries in Team Sport: A between-Sports Comparison in Basketball and Handball Athletes. *Int J Environ Res Public Health*.
- Beynon, B., Renström, P., Alosa, D., Baumhauer, J., & Vacek, P. (2001). Ankle ligament injury risk factors: a prospective study of college athletes. *J Orthop Res*.
- Bishop, C. M., Turner, A. P., & Read, P. P. (2018c). Training Methods and Considerations for Practitioners to Reduce Interlimb Asymmetries. *Strength and Conditioning Journal*.
- Bishop, C., Brashill, C., Abbott, W., Read, P., Lake, J., & Turner, A. (2021a). Jumping asymmetries are associated with speed, change of direction speed, and jump performance in elite academy soccer players. *Journal of Strength and Conditioning Research*.
- Bishop, C., Lake, J., Loturco, I., Papadopoulos, K., Turner, A., & Read, P. (2021b). Interlimb Asymmetries: The Need for an Individual Approach to Data Analysis. *J Strength Cond Res*.
- Bishop, C., Pereira, L., Reis, V., Read, P., Turner, A., & Loturco, I. (2020). Comparing the magnitude and direction of asymmetry during the squat, countermovement and drop jump tests in elite youth female soccer players. *J Sports Sci*.
- Bishop, C., Read, P., Chavda, S., & Turner, A. (2016). Asymmetries of the Lower Limb: The Calculation Conundrum in Strength Training and Conditioning. *Strength and Conditioning Journal*.
- Bishop, C., Read, P., Lake, J., Chavda, S., & Turner, A. (2018a). Interlimb Asymmetries: Understanding How to Calculate Differences From Bilateral and Unilateral Tests. *Strength and Conditioning Journal*.
- Bishop, C., Turner, A., & Read, P. (2018b). Effects of inter-limb asymmetries on physical and sports performance: a systematic review. *Journal of Sports Sciences*.
- Booher, L., Hench, K., Worrell, T., & Stikeleather, J. (1993). Reliability of Three Single-Leg Hop Tests. *Journal of Sport Rehabilitation*, 165-170.
- Brown, S., Feldman, E., Cross, M., Helms, E., Marrier, B., Samozino, P., & Morin, J. (2017). The Potential for a Targeted Strength-Training Program to Decrease Asymmetry and Increase Performance: A Proof of Concept in Sprinting. *Int J Sports Physiol Perform*.
- Brumitt, J., Heiderscheit, B., Manske, R., Niemuth, P., & Rauh, M. (2013). Lower extremity functional tests and risk of injury in division iii collegiate athletes. *Int J Sports Phys Ther*.

- Chalmers, S., DeBenedictis, T., Zacharia, A., Townsley, S., Gleeson, C., Lynagh, M., . . . Fuller, J. (2018). Asymmetry during Functional Movement Screening and injury risk in junior football players: A replication study. *Scan J Med Sci Sports*.
- Clijisen, R., & Hohenauer, E. (2022, July 8). Advising meeting regarding the discussion writing. (G. Meret, Interviewer)
- Dingenen, B., Truijen, J., Bellemans, J., & Gokeler, A. (2019). Test-retest reliability and discriminative ability of forward, medial and rotational single-leg hop tests. *Knee*.
- Domínguez-Díez, M., Castillo, D., Raya-González, J., Sánchez-Díaz, S., Soto-Célix, M., Rendo-Urteaga, T., & Lago-Rodríguez, Á. (2021). Comparison of multidirectional jump performance and lower limb passive range of motion profile between soccer and basketball young players. *PLoS One*.
- Dos'Santos, T., Thomas, C., Jones, P., & Comfort, P. (2019). Assessing Asymmetries in Change of Direction Speed Performance: Application of Change of Direction Deficit. *J Strength Cond Res*.
- Engström, B., Johansson, C., & Törnkvist, H. (1991). Soccer injuries among elite female players. *Am J Sports Med*.
- FIFA. (n.d.). *Women's football member associations survey report 2019*. Retrieved from digitalhub.fifa.com: <https://digitalhub.fifa.com/m/231330ded0bf3120/original/nq3ensohyxpuxovcovj0-pdf.pdf>
- Fort-Vanmeerhaeghe, A., Bishop, C., Buscà, B., Vicens-Bordas, J., & Arboix-Alió, J. (2021). Seasonal variation of inter-limb jumping asymmetries in youth team-sport athletes. *J Sports Sci*.
- Fousekis, K., Tsepis, E., & G, V. (2010). . Lower limb strength in professional soccer players: profile, asymmetry, and training age. *J Sports Sci Med*.
- Gonzalo-Skok, O., Morenzo-Azze, A., Arjol-Serrano, J. L., Tous-Fajardo, J., & Bishop, C. (2019). A Comparison of Three Different Unilateral Strength Training Strategies to Enhance Jumping Performance and Decrease Inter-Limb Asymmetries in Soccer Players . *International Journal of Sports Physiology and Performance*.
- Gonzalo-Skok, O., Tous-Fajardo, J., Suarez-Arrones, L., Arjol-Serrano, J., Casajús, J., & Mendez-Villanueva, A. (2016). A Single-Leg Power Output and Between-Limbs Imbalances in Team-Sport Players: Unilateral Versus Bilateral Combined Resistance Training. *Int J Sports Physiol Perform*.
- Gustavsson, A., Neeter, C., Thomeé, P., Silbernagel, K., Augustsson, J., Thomeé, R., & Karlsson, J. (2006). A test battery for evaluating hop performance in patients with an ACL injury and patients who have undergone ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc*.
- Hart, N., Nimphius, S., Weber, J., Spiteri, T., Rantalainen, T., Dobbin, M., & Newton, R. (2016). Musculoskeletal Asymmetry in Football Athletes: A Product of Limb Function over Time. *Med Sci Sports Exerc*.
- Helme, M., Tee, J., Emmonds, S., & Low, C. (2021). Does lower-limb asymmetry increase injury risk in sport? A systematic review. *Phys Ther Sport*.
- Keeley, D., Plummer, H., & Oliver, G. (2011). Predicting asymmetrical lower extremity strength deficits in college-aged men and women using common horizontal and vertical power field tests: a possible screening mechanism. *J Strength Cond Res*.
- Kockum, B., & Heijne, A. (2015). Hop performance and leg muscle power in athletes: Reliability of a test battery. *Phys Ther Sport*.
- Lambert, C., Pfeiffer, T., Lambert, M., Brozat, B., Lachmann, D., Shafizadeh, S., & Akoto, R. (2020). Side Differences Regarding the Limb Symmetry Index in Healthy Professional Athletes. *Int J Sports Med*.

- Lockie, R., Callaghan, S., Berry, S., Cooke, E., Jordan, C., Luczo, T., & Jeffriess, M. (2014). Relationship between unilateral jumping ability and asymmetry on multidirectional speed in team-sport athletes. *J Strength Cond Res*.
- Loturco, I., Pereira, L., Freitas, T., Alcaraz, P., Zanetti, V., Bishop, C., & Jeffreys, I. (2019). Maximum acceleration performance of professional soccer players in linear sprints: Is there a direct connection with change-of-direction ability? *PLoS One*.
- Madrugá-Parera, M., Bishop, C., Read, P., Lake, J., Brazier, J., & Romero-Rodriguez, D. (2020). Jumping-based Asymmetries are Negatively Associated with Jump, Change of Direction, and Repeated Sprint Performance, but not Linear Speed, in Adolescent Handball Athletes. *J Hum Kinet*.
- Madsen, L., Booth, R., Volz, J., & Docherty, C. (2020). Using Normative Data and Unilateral Hopping Tests to Reduce Ambiguity in Return-to-Play Decisions. *J Athl Train*.
- Maloney, S., Richards, J., Nixon, D., Harvey, L., & Fletcher, I. (2017). Do stiffness and asymmetries predict change of direction performance? *J Sports Sci*.
- Mortaza, N., Ebrahimi, I., Jamshidi, A., Abdollah, V., Kamali, M., Abas, W., & Osman, N. (2012). The effects of a prophylactic knee brace and two neoprene knee sleeves on the performance of healthy athletes: a crossover randomized controlled trial. *PLoS One*.
- Munro, A., & Herrington, L. (2011). Between-session reliability of four hop tests and the agility T-test. *J Strength Cond Res*.
- Murphy, D., Connolly, D., & Beynon, B. (2003). Risk factors for lower extremity injury: a review of the literature. *Br J Sports Med*.
- Myer, G., Brent, J., Ford, K., & Hewett, T. (2011). Real-time assessment and neuromuscular training feedback techniques to prevent ACL injury in female athletes. *Strength Cond J*.
- Ostenberg, A., & Roos, H. (2000). Injury risk factors in female European football. A prospective study of 123 players during one season. *Scand J Med Sci Sports*.
- Pardos-Mainer, E., Bishop, C., Gonzalo-Skok, O., Nobari, H., Pérez-Gómez, J., & Lozano, D. (2021). Associations between Inter-Limb Asymmetries in Jump and Change of Direction Speed Tests and Physical Performance in Adolescent Female Soccer Players. *Int J Environ Res Public Health*.
- Pasanen, K., Parkkari, J., Kannus, P., Rossi, L., Palvanen, M., Natri, A., & Järvinen, M. (2008a). Injury risk in female floorball: a prospective one-season follow-up. *Scand J Med Sci Sports*.
- Pasanen, K., Parkkari, J., Rossi, L., & Kannus, P. (2008b). Artificial playing surface increases the injury risk in pivoting indoor sports: a prospective one-season follow-up study in Finnish female floorball. *Br J Sports Med*.
- Pereira, L., Nimphius, S., Kobal, R., Kitamura, K., Turisco, L., Orsi, R., . . . I, L. (2018). Relationship Between Change of Direction, Speed, and Power in Male and Female National Olympic Team Handball Athletes. *J Strength Cond Res*.
- Raya-González, J., Bishop, C., Gómez-Piqueras, P., Veiga, S., Viejo-Romero, D., & Navandar, A. (2020). Strength, Jumping, and Change of Direction Speed Asymmetries Are Not Associated With Athletic Performance in Elite Academy Soccer Players. *Frontiers in Psychology*.
- Raya-González, J., Clemente, F., & Castillo, D. (2021). Analyzing the Magnitude of Interlimb Asymmetries in Young Female Soccer Players: A Preliminary Study. *Int J Environ Res Public Health*.
- Reid, A., Birmingham, T., Stratford, P., Alcock, G., & Giffin, J. (2007). Hop testing provides a reliable and valid outcome measure during rehabilitation after anterior cruciate ligament reconstruction. *Phys Ther*.

- Risberg, M., Holm, I., & Ekeland, A. (1995). Reliability of functional knee tests in normal athletes. *Scand J Med Sci Sports*.
- Sammelstelle für die Statistik der Unfallversicherung UVG, S. (2020). *Unfallstatistik UVG 2020*. Luzern: Suva.
- Scinicarelli, G., Trofenik, M., Froböse, I., & Wilke, C. (2021). The Reliability of Common Functional Performance Tests within an Experimental Test Battery for the Lower Extremities. *Sports (Basel)*.
- Smith, C., Chimera, N., & Warren, M. (2015). Association of y balance test reach asymmetry and injury in division I athletes. *Med Sci Sports Exerc*.
- Snellman, K., Parkkari, J., Kannus, P., Leppälä, J., Vuori, I., & Järvinen, M. (2001). Sports injuries in floorball: a prospective one-year follow-up study. *Int J Sports Med*.
- Steidl-Müller, L., Hildebrandt, C., Müller, E., Fink, C., & Raschner, C. (2018). Limb symmetry index in competitive alpine ski racers: Reference values and injury risk identification according to age-related performance levels. *J Sport Health Sci*.
- Stephens, T. I., Lawson, B., DeVoe, D., & Reiser, R. I. (2007). Gender and Bilateral Differences in Single-Leg Countermovement Jump Performance with Comparison to a Double-Leg Jump. *Journal of Applied Biomechanics*.
- Tanaka, M., LiBrizzi, C., Rivenburgh, D., & Jones, L. (2021). Changes in U.S. girls' participation in high school sports: implications for injury awareness. *Phys Sportsmed*.
- Tervo, T., & Nordström, A. (2014). Science of floorball: a systematic review. *Open Access J Sports Med*.
- Thomas, T., Comfort, P., & Jones, P. (2018). Comparison of Change of Direction Speed Performance and Asymmetries between Team-Sport Athletes: Application of Change of Direction Deficit. *Sports (Basel)*.
- UEFA. (n.d.). *Women's football across the national associations 2016/17*. Retrieved from uefa.com: https://www.uefa.com/MultimediaFiles/Download/OfficialDocument/uefaorg/Women%27sfootball/02/43/13/56/2431356_DOWNLOAD.pdf
- Van Lange, P., Manesi, Z., Meershoek, R., Yuan, M., Dong, M., & Van Doesum, N. (2018). Do male and female soccer players differ in helping? A study on prosocial behavior among young players. *PLoS ONE*.
- van Melick, N., Meddeler, B., Hoogeboom, T., Nijhuis-van der Sanden, M., & van Cingel, R. (2017). How to determine leg dominance: The agreement between self-reported and observed performance in healthy adults. *PLoS One*.
- Viera, A., & Garret, J. (2005). Understanding interobserver agreement: the kappa statistic. *Fam Med*.
- Wikström, J., & Andersson, C. (1997). A prospective study of injuries in licensed floorball players. *Scand J Med Sci Sports. Scand J Med Sci Sports*.
- Wilke, C., Grimm, L., Hoffmann, B., & Froböse, I. (2018). Funktionelle Tests als Entscheidungskriterium für die Rückkehr von Sportlern nach einer Ruptur der vorderen Kreuzbandes. *Sportverletz Sportschaden*.
- Zwahlen, J., Boss, C., Gisler, P., Spöring, L., & Sprecher, S. (2013). *Analyse der Entwicklung und der aktuellen Situation des weiblichen Unihockeysports in der Schweiz*. Bern: Seminararbeit am Institut für Sportwissenschaft der Universität Bern.

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This study investigates lower inter-limb asymmetries in female youth soccer and floorball players, addressing the underexplored area of sport-specific differences. The research recognizes the higher prevalence of asymmetries in women and employs a robust methodology, including a diverse test battery of six unilateral jumping tasks.

The findings reveal a significantly higher magnitude of asymmetries in soccer compared to floorball, suggesting sport specificity. Specific jump types also exhibit varying effects on asymmetries. The study concludes that inter-limb asymmetries may be both task and sport-specific, independent of leg dominance.

The practical implication for strength and conditioning coaches is to assess athletes' asymmetries using a sport-specific test battery to mitigate potential negative impacts on performance and injury risk. Overall, this study provides valuable insights into inter-limb asymmetries, contributing to the sports science field.